THE USE OF OIL ENGINES FOR PUMPING[1]

By C. R. Knowles

Internal combustion engines using gasoline as fuel have long been in use for railway water service. The increased consumption of water, necessitating larger pumps and heavier power, together with the increase in the cost of gasoline, has made it necessary to look to a cheaper fuel in the operation of water stations.

In order to utilize the existing equipment many of the gasoline engines now in service have been converted to kerosene and distillate engines by the addition of attachments for preheating the oil to or near the flashing point before the oil enters the cylinder. These attachments consist of generators or mixing chambers wherein the oil is heated by the exhaust of the engine. They are made in various sizes and types, both for throttling and for hit and miss governors. With these attachments the engine is generally started on gasoline and is allowed to run on this fuel until the cylinder and generator are heated, when the oil is cut in. On other types a retort is provided where the oil is converted into a vapor or gas by heating the retort with a blow torch. Either method requires from five to ten minutes to start an engine running on oil. Electric ignition is used, as with gasoline engines. Very little carbon trouble is experienced with the use of these attachments and the lubrication required is about the same as with a gasoline engine.

A series of tests of various fuels were made pumping against a total head of 61 feet, with an 8 x 10 inch single cylinder double acting pump direct connected to a 6 h.p. four cycle horizontal gasoline engine equipped to run on kerosene and distillates as well as gasoline, controlled by a throttling governor. This engine was one of the first gasoline engines ever equipped to operate on low grade oils and has been continually operated on distillates from 36° to 32° Baumé for the past six years.

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The fuels used were:

TABLE 1

Distillate	40.0° Baumé	Flash, 150	Burn, 145
Methyl alcohol	40.5° Baumé	Flash and burn at room temperature.	
Kerosene	46.0° Baumé	Flash, 124	Burn, 170
Gasoline	62.0° Baumé	Flash and burn at room temperature.	
Motor spirits	58.0° Baumé	Flash and burn at room temperature.	

Efficiency fuel tests

	DISTILLATE	ALCOHOL	KEROSENE	GASOLINE	MOTOR SPIRITS
Pints per hour	6.0	7.0	6.0	7.0	6.0
Pounds fuel per hour	5.145	6.062	4.943	5.373	4.755
Pounds of fuel per h.p.h.	1.91	2.22	1.91	1.97	1.74
Pump, revolutions per minute	43.35	43.32	43.54	43.72	43.79
Pumped, gallons per minute	175.0	177.8	176.8	176.8	178.1
Cost of fuel per gallon	0.04625	0.40	0.08	0.15	0.13
Cost fuel per hour	0.0347	0.35	0.06	0.1313	0.0975
Cost of fuel per h.p.h.	0.0129	0.1282	0.0220	0.0483	0.0356
Cost per 1000 gallons	0.0033	0.0327	0.0056	0.0124	0.0092
	Deg.	Deg.	Deg.	Deg.	Deg.
Temperature of cylinder start	165	90	135	46	46
Temperature of cylinder run	145	145	145	130	125
Temperature of inlet air	110	125	120	60	60

As will be seen from the above figures the distillate is the most economical of the fuels used. The cost per water horse power being 53 per cent of the cost of pumping with kerosene, and only 27 per cent of the cost of pumping with gasoline. The high cost of alcohol eliminates it as a fuel for pumping water and the result of the test is merely submitted as a comparative feature. No doubt better results could have been obtained by reducing the area of the combustion chamber as more compression is required to secure economical results from the use of alcohol in internal combustion engines. The power obtained from the use of kerosene was practically the same as from the distillate, the only difference being in the price of the two fuels. The gasoline test shows such results as might be obtained from the average gasoline engine under the same condi-

tions. The fuel known as motor spirits, which has been widely advertised as a substitute for gasoline, operates under practically the same conditions as gasoline. An objectionable feature of this oil is a disagreeable odor and it would perhaps be undesirable to use in certain localities.

A 12 h.p. four cycle gasoline engine with a hit and miss governor pulling a $7\frac{1}{2}$ x 30 inch working barrel in a deep well was equipped with a generator for burning low grade oils. Comparative tests showed that the engine consumed the same amount of 39 degrees distillate per horse power hour as gasoline. The difference in the cost of the two fuels, however, showing a saving of $.0434 per horse power hour in the use of the distillate. The cost of pumping water at this point is comparatively high, due to the fact that the water is pumped with a single acting deep well cylinder.

The tabulated results obtained follow:

TABLE 2

	GASOLINE	DISTILLATE
Pints per hour	14.0	14.0
Pounds of fuel per hour	11.746	12.005
Pounds fuel per h.p.h	3.458	3.53
Pump, revolutions per minute	24.0	24.0
Pumped, gallons per minute	124.0	124.0
Cost fuel per gallon	0.125	0.04625
Cost of fuel per hour	21.875	8.093
Cost fuel per h.p.h	0.0643	0.0209
Cost per 100 gallons water	0.0029	0.0108

The heavy oil engine is a comparatively recent development and is being extensively used in railway water stations, as well as for other service. The most popular engine of this type is the two cycle oil engine constructed in units of 50 h.p. and under, using heavy oil as fuel. This type of engine is very often confused with high compression engines operating on the Diesel principle or with the converted gasoline engine using kerosene and distillates through a carburetor or mixing valve.

The cycle of operation of the Diesel engine is to compress air to 450 or 500 pounds per square inch, generating a temperature of approximately 540°C. Into this highly heated air the fuel is injected during the return or second stroke of the piston in a finely atomized

form at such a rate as will maintain a constant temperature while burning and in such quantity as will do the required work for each stroke. The expanded gases of combustion are forced out of the cylinder during the third stroke, while the fourth stroke draws fresh air into the cylinder. This is the sequence of events in a four cycle engine.

By expelling the burned gases with fresh air the necessary functions can be performed in two strokes of the piston, producing the so called two cycle engine.

The above mentioned engine should not, however, be confused with the two cycle oil engine as used in railway and other pumping stations and termed the Semi-Diesel engine. In order to avoid the high compression pressure and the resulting complication of design necessary in the Diesel engine this so called Semi-Diesel engine has been devised, which does not compress the air sufficiently to raise the temperature to such a point that it will spontaneously ignite the injected fuel. It is this type of engine which we have to deal with, particularly with the two cycle valveless injection engine, in which the compression has been reduced, adding the required temperature in a heated combustion chamber. This engine is governed by throttling the oil supply and ignition is accomplished by means of a hollow ball. This ball is heated by a blow torch before starting, but after the engine is running the heat is maintained by the successive explosions. The fuel is introduced through fuel valves similar to the Diesel engine, but much less compression of air is required. The compression of the Semi-Diesel engines being from 80 to 130 pounds. Crank case compression is $1\frac{3}{4}$ to $3\frac{1}{2}$ pounds.

Although these engines have a theoretically less efficient heat cycle than the Diesel they gain in simplicity of construction.

Intelligent lubrication is essential to the proper operation of the oil engine. Improper lubrication contributes largely to oil engine trouble. The high speeds and temperature at which these engines work necessitate a continuous and skillful use of good oil. A great deal depends upon the proper lubrication of an engine of this type and the prevention of the carbon forming in the cylinder. The destruction of the lubricating oil by combustion cannot be prevented. Just what occurs to the oil in an internal combustion engine cannot be entirely explained, but there is no doubt that a great deal of it is burned along with the fuel oil and as long as this is true it is necessary that complete combustion takes place, in order

that a residue of unburnt oil is not left in the cylinder in the form of carbon.

The lubrication of the steam engine or pump is comparatively simple. In steam engines there is a certain amount of moisture to assist lubrication, but the flames of an oil engine dry the internal surfaces and unless the proper amount of oil is applied, the cylinder, piston and rings soon begin to suffer. In a steam engine or pump the temperature will at the most reach about 500 degrees while in an oil engine it rises to as high as 2500 degrees. Added to this is the fact that the piston speed of an internal combustion engine is from three to four times that of a steam engine or pump. Consequently the oil engine requires a different method of lubrication and a great deal more of it.

Engines of this type are liable to suffer from carbon trouble and resultant deterioration due to the fact that an excess of oil injected into the cylinder breaks up into volatile compounds, such as the naphthas, heavy tar like oils and free carbon.

Overloading the engine also will cause carbon trouble. When the engine is working up to its maximum power, a momentary overload will cause an excess of oil, and the resultant accumulation of carbon due to the fact that the oil engine is not flexible enough to adjust itself instantly to the varying loads, as does a steam engine or pump.

The carbon troubles may be reduced to the minimum by the use of the proper oil. Fuel oils vary in quality as do hard and soft coal and even to a greater extent. As a result some oils are better suited for use in oil engines than others. While it is possible to burn almost any oil that will flow freely, the best results are to be obtained from oils of a parafine base from 30 to 36° Baumé.

A number of tests were conducted on a 25 h.p. oil engine with a 10 x 14 inch cylinder belted to a 10 x 12 inch duplex power pump, using seven different kinds of oil, ranging from a heavy fuel oil of an asphalt base to a light distillate of a parafine base. A brief description of the oils used follows:

No. 1. Diesel fuel oil, 26° Baumé made from asphaltum base crudes from Texas and Louisiana fields.

No. 2. Gulf fuel oil, 24° Baumé, made from asphaltum base crudes from Oklahoma fields.

No. 3. Narico distillate, 39° Baumé, made from semi-parafine base mid-continent crudes.

No. 4. Motor oil, 42° Baumé, made from parafine base crudes from Cushing Oklahoma fields.

No. 5. Navy fuel oil, 26° Baumé, made from asphaltum base crudes from Texas and Oklahoma fields.

No. 6. No. 1 fuel oil, 32° Baumé, a nonsulphur oil parafine base from Illinois crudes.

No. 7. Kentucky crude oil 32.5° Baumé parafine base.

The following table gives the results obtained from the use of the above oils. The costs given cover the fuel only:

TABLE 3

	1	2	3	4	5	6	7
Gallons of oil used per hour.	1.51	2.29	2.04	1.88	2.19	2.00	2.10
Pounds of oil used per hour.	11.30	17.33	14.07	12.20	16.38	14.40	15.07
Pounds of oil used per w.h.p.	1.02	1.12	0.98	0.80	1.01	0.96	0.85
Engine r.p.m...	346.0	337.0	345.0	345.0	342.0	338.0	328.0
Pump r.p.m....	40.0	39.0	40.0	40.0	40.0	39.0	38.0
Gallons pumped per minute...	444.0	603.0	583.0	592.0	586.0	580.0	577.0
Cost of oil per gallon........	0.029	0.029	0.031	0.03	0.029	0.025	0.016
Cost of oil per hour.........	0.044	0.066	0.063	0.056	0.063	0.05	0.035
Cost per 1000 gallons.......	0.0016	0.0019	0.0022	0.0016	0.0018	0.0015	0.0009

While these tests are not conclusive they indicate the wide range of fuels it is possible to burn in these engines.

The following tables give the result of tests conducted in pumping with 4 inch centrifugal pumps using two cycle Semi-Diesel oil engines for power, one pump being driven by a 25 h.p. horizontal engine and the other by a 25 h.p. vertical engine, both pumps being belt driven.

Table 4 gives the result of one hour's run, while table 5 gives the hours run and cost for a period of four months for each engine.

Tables 6 and 7 show the results obtained in pumping with a 25 h.p. horizontal two cycle heavy oil engine belted to a 10 x 12 inch double acting duplex power pump and a 30 h.p. vertical two cycle heavy oil engine belted to a 11 x 12 inch single acting triplex power pump.

TABLE 4

Test one hour's run

	HORIZONTAL ENGINE	VERTICAL ENGINE
R.p.m. engine	315.0	380.0
R.p.m. pump	1587.0	1320.0
Gallons pumped per minute	571.0	571.0
Total head in feet	77.38	79.69
Fuel oil consumed in gallons	2.25	2.65
Water horse power	11.15	11.5
Brake horse power	21.4	22.1
Cost fuel oil per million gallons	$1.67	$1.97.
Cost of fuel oil per gallon	0.0253	0.0253
Cost per h.p.h	0.0026	0.0030

TABLE 5

Cost of fuel and lubricants four months' run each engine

	HORIZONTAL ENGINE	VERTICAL ENGINE
Total number of hours run	331	316
Gallons water pumped	9,930,000	9,480,000
Cost of kerosene	$3.78	$1.50
Cost of fuel oil	18.01	18.47
Cost of lubricants	9.20	10.20
	$30.99	$30.17
Cost per 1,000,000 gallons	$3.12	$3.18

TABLE 6

Test one hour's run

	DUPLEX PUMP HORIZONTAL ENGINE	TRIPLEX PUMP VERTICAL ENGINE
R.p.m. engine	342	396
R.p.m. pump	40	44
Gallons pumped per minute	586	640
Total head in feet	104	106
Fuel oil consumed in gallons	2.19	2.70
Water horse power	15.33	17.5
Brake horse power	20.44	23.33
Cost fuel oil per million gallons pumped	$1.80	$2.00
Cost fuel oil per gallon	0.029	0.029
Cost per h.p.h	0.0031	0.033

TABLE 7

Cost of fuel and lubricants four months' run each engine

	DUPLEX PUMP HORIZONTAL ENGINE	TRIPLEX PUMP VERTICAL ENGINE
Total number of hours run	687	677
Gallons water pumped	24,732,000	24,372,000
Cost of kerosene	8.52	9.78
Cost of fuel oil	26.26	31.37
Cost of lubricants	17.10	22.04
Total cost	51.88	63.19
Cost per million gallons	$2.09	$2.54

Table 6 giving the results for one hour's run and table 7 cost for a period of four months for each engine.

Although the oil engine cannot yet be considered as fully developed, it has passed the experimental stage, and while it is perhaps, not as reliable under all conditions as a steam engine or pump, much of the prejudice against the oil engine is undoubtedly due to lack of experience in handling. With the present imperfect knowledge of what the engine is capable of doing and of what particular oils may be burned in it, one cannot speak conclusively, but there is no doubt that the future of the engine is assured.